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Linear Parameters Causing Landslides: A Case Study of Distance to the Road, Fault, Drainage

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Abstract

Choosing the right parameters for the study area is a compelling process. Parameters provide different results when applied to different areas, and some of these parameters can be evaluated generally, while others reflect the characteristics and properties of the areas. A comprehensive literature study was conducted for this purpose. By conducting this study, only the studies in which the distance to the road, drainage and fault were effective in the formation of landslides were evaluated. 64 landslide areas in Turkey were selected for samplings used in the study. Literature research and case studies were compared, and the effects of the distance from the road, fault and drainage on landslides were investigated. Landslide-prone areas were determined according to the classification ranges for the parameters. The classification ranges were selected according to the literature. This study, which is different from the examples in the literature, was carried out in the form of comprehensive literature research and a comparison of analyzes.

1. Introduction

The distance to the linear parameters is an important factor in a landslide. The distance to road, fault and drainage is frequently preferred for these parameters. In the literature, while some researchers were using all 3 parameters in the same study, some researchers evaluated only 2 of them. In most studies, only one of the three was preferred.

Wang and Li [1], Kornejady et al. [2], Chen et al. [3], Hong et al. [4], Jaafari et al. [5], Panchal and Shrivastava [6], Rozos et al. [7], Kumtepe et al. [8] used all three parameters in their studies. Pourghasemi and Rossi [9] determined that landslides were reduced when moving away from drainage, roads and faults, according to expert opinion. Tanoli et al. [10], Zhang et al. [11], Kamp et al. [12], Blesius and Weirich [13], and Van Westen et al. [14] emphasized that it is very important for landslide susceptibility analysis to use distance to river and highway. According to Hong et al. [4], Poudyal et al. [15], Preuth et al. [16], and Lee and Chi [17], geological faults and roads are accepted as factors that can affect landslides. Bai et al. [18], Özdemir [19], and Barredo et al. [20] evaluated the distance of the river and fault as a landslide susceptibility factor.

One of the factors that destroys the natural topography and affects the stability in slopes is the situation of the existing road networks [21-25]. The construction of infrastructural elements like roads is accepted as human construction activity that affects slope instability. Slopes are shears for road construction, vegetation is altered, and highway tourism increases because of the economic activity near the roads [26]. The general concept is that the horizontal and natural sections around a road are more susceptible to landslides [7]. For this reason, landslides can occur on roads and around the edges of slopes that are affected by roads [27-30]. In other words, landslides can occur in slopes where roads intersect [31]. Many researchers claim that the existence of roads in mountainous areas increases the change that landslides will form [32-38]. Because of the reasons these explanations reveal, the road proximity parameter is used in landslide susceptibility map studies [2, 39-41]. The construction of infrastructure elements like roads is accepted as human construction

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activity that affects slope instability.

One of the parameters chosen in the preparation of landslide susceptibility maps is the structural elements. In particular, faults represent suitable conditions for landslides [42]. Faults create a weak line or region of heavily crushed rocks [40]. Generally, the distance or proximity to faults parameter is used. There may be a significant relationship between the landslide settlement areas' proximity to the fault [43]. Tectonic activities can play an important role in large-scale landslides [44]. Zhang et al. [11] stated that the landslide hazard is closely related to the distance from the faults. In the literature, other studies are prepared to measure the effects of the distance from the faults on landslides [45-51]. Pourghasemi and Rossi [9] defend that there is a direct relationship between the distance from the faults and the frequency of landslides. Çevik and Topal [52] stated an inverse relationship exists between the landslide distribution and the distance to the fault. In the literature, most researchers stated that landslides are frequently seen in areas in proximity to the fault [53-56], and landslide susceptibility/hazard/risk will increase in said areas [57, 58]. Likewise, landslides decrease as they move away from fault lines [9, 59-61]. Therefore, the parameter is considered one of the main causes of landslides [62] and it is recommended to use it as a parameter [63]. Çellek et al. [64] searched nearly 300 studies about landslide susceptibility and listed the most used parameters. They stated that distance to the fault is ranked 9th among the literature's top 10 most preferred parameters. This parameter was used in 120 studies. Gökçeoğlu and Aksoy [65] field observations have shown that most of the landslides occurred very close to faults in their study area. Mathew et al. [66] observed that faults are one of the most important factors affecting the stability of slopes in the study area. Thus, they selected the fault buffer as one of the independent variables. Özşahin [67] conducted a study in an area with active faults. As a result, he stated that the distance from the faults effectively affected the landslide. Likewise, Korkmaz [68] noted that the faults in the study area affect the landslide. Xu et al. [6], Regmi et al. [69] and Wang et al. [63] stated that landslides occur along the fault line in the study area, and landslides decrease sharply as they move away from them. Ahmed et al. [2014] stated that the most likely triggering factor for large rock mass move in the study areas is proximity to the fault [30].

In contrast, some studies argue that proximity to the fault isn't the main parameter in the landslide susceptibility study. Kayastha et al. [71] stated that they expect landslides to occur near the faults and decrease as the distance increases. However, they found that most landslides in their area occurred more than 100 meters away from faults. In this case, they concluded that faults and folds aren't the main factors for landslides. Likewise, Zhang et al. [72] stated in the literature that many studies had associated landslides with proximity to the fault, but the data in their study area don't reflect this.

There are more studies that argue that proximity to the fault isn't the main parameter in the landslide susceptibility study. Kayastha et al [71] stated that they expect landslides to occur near the faults and decrease as the distance increases. However, they found that the majority of landslides in their area also occurred more than 100 meters away from faults. In this particular case, they concluded that faults and folds aren't the main factors for landslides to occur. Likewise, Zhang et al. [72] stated in the literature that many studies have associated the occurrence of landslides with proximity to the fault, but the data in their study area don't reflect this.

In many parts of the world, drainage plays an important role in landslides [73, 74]. Because a soil close to the drainage may have higher water content than any other soil far from the drainage [75].

In many studies on the preparation of landslide susceptibility maps, researchers have used the proximity of the drainage as a parameter in landslide evaluations by making use of field observations [1-3, 10, 38, 49, 50, 56, 58, 76-78]. More than half of the landslides in Turkey are observed in the generation of active faults around 60 km wide [79]. This study examined landslide studies conducted in various regions of the world. Landslides that had occurred in areas near faults in Turkey have been analyzed. As a result of the study, the faults in landslide areas were selected and compared with the literature in Turkey.

The effects of proximity to the drainage on landslide susceptibility can be evaluated in two ways. Firstly, it is seen that the discontinuity surfaces on the unstable slope can't resist the pull of gravity, and the collapse facilitates ground movements [80].

Latter relates to the degree of saturation of the material on the slope. The effects of groundwater and surface water also increase with the proximity to the drainage network. The drainages can negatively affect stability by eroding the slopes or saturating the bottom of the material until the water level rises. Therefore, the proximity of drainage is an important factor in stability [3, 49, 50].

A comprehensive field survey should be conducted to determine the effects of drainage on the slope. Statistical analysis shows that a strong relationship can be observed between landslide distribution and distance to drainage [18]. However, in determining the impact on landslides, it is uncertain how to use the main drainages or tributaries that make up the drainage network, and in which distances [81].

Hasekioğulları [82] states that 37 of its studies were used as a distance to the river. The usage rate of this parameter, which is evaluated among topographic parameters and called drainage, is expressed as 72.73% in the studies examined by Süzen and Kaya [83]. Çellek et al. [64], found that distance to drainage was the 6th most preferred parameter with 153 studies in 300 studies that they examined.

2. Effects on Parameters of Landslides

The parameter of distance to road, fault and drainage disrupts the landslide susceptibility. Parameters separately or together create this effect. The effects on landslides are investigated by using many methods and techniques. The literature for the preparation of linear parameter maps utilizes field studies, topographic maps for studied areas, prepared data sets or linear parameter maps, aerial photographs, and various satellite data from low-resolution images such as Google Earth to high-resolution images such as the multispectral LISS-4 satellite, Aster, and QuickBird. Apart from this, there are those that gather current data with road, fault, drainage networks, GPS, and navigation devices. The researchers digitized these maps using certain ArcGIS programs [66, 82].

2.1. The Effect of the Road Distance Parameter on Landslides

Based on its position on the slope, a previously or newly constructed road could cause landslides [84], but the rate of landslide decreases as the age of the road increases [85]. Road construction alters vegetation [22, 28, 57, 86]. This increases human activity with economic activity conducted in areas close to the roads [26, 87]. High slope changes the stress status and slope balance [32, 88]. It causes the application of static and dynamic loads [11, 54, 55]. The traffic frequent vibrations that vehicles cause [23, 46, 57, 64, 89, 90] trigger the fragmenting-loosening [38, 50] of rocks with bursts in an uncontrolled manner.

Road construction works and over vibration frequency generated by these works are effective in the occurrence of landslides [1-3, 9, 10] because it causes the loss of toe support based on the places where the roads pass the slope and because it would bring additional loads to the slope. On slopes that were balanced before road construction, cracks occur due to increased tension in the back of the slope after the construction [90]. Cracks that form trigger landslide events, as they are being subjected to negative effects such as water input that can come from outside [11, 58, 90]. Gravel materials on roads were designed and compressed to endure heavy loads to make surfaces flat and impermeable. During severe rainfall, they make road surfaces impermeable and provide rapid land flow and surface flow [23, 58].

Despite this, a certain section of the road can function as a barrier, a network resource, a network pool, or a corridor for water flow [91-93]. It can indirectly cause landslides by increasing the water concentration in the slope, including saturated slopes [11, 30]. Another crucial point is the change of natural hydraulic roads that may water to concentrate in the imbalanced sections of the slope [27]. In addition to these effects, roads cause the emergence of ground waters on the surface, because the roads interrupt the continuity of the slope, and the waters are collected by road drainage systems. Since inadequately or incorrectly projected drainage facilities are unable to securely evacuate these waters with precipitation after severe rainfall, they stand out as an element that triggers landslides [94].

In the literature there are researchers who have identified landslides originating from road construction work in their study areas [95]. Tangestanı [96] reported that development activity in the Kakan region caused the increase of road density. Field observations demonstrate that the possibility increases for slides in places where roads pass by worn, excessively worn, or semicircular rock units or by loosened soil in steep slopes. Dahal [97] reported that roads constructed without taking precautions negatively affected slopes and that many landslides were identified along newly constructed roads. Abedini et al. [76] used this parameter because landslides occurred during reconstruction and road expansion in their study area. Ataol and Yeşilyurt [98] determined that many new landslides and mudslides materialized during road construction work.

Sidle [99] revealed in their study that mass movements were between 30 and 340 times greater in slopes that passed through roads than those that didn't. Piehl et al. [100], reported in a study they conducted in Oregon that landslides that occur based on roads constitute 72% of all landslides. Çellek [95] reported that many landslides occurred during the work for a newly constructed road and that the construction work triggered mass movements, even though the study area wasn't a landslide region. Demir [101] and Regmi et al. [69] reported that landslides occurred in their study area due to construction work on the road. Alexakis et al. [102] accepts the expansion of highway networks as a key factor for the separation of mudslide hazard zones.

2.1.1. The Effect of Distance to Faults with Other Parameters on Landslide

The road parameter is an anthropological factor that causes landslides. It is evaluated together with its effect on landslides, rock bursts, vibration frequency of vehicles passing by on the road, slope change, adding of load to the toe, presence of touristic activity along the road [restaurants and businesses], the change in vegetation, and the effects of precipitation and drainage water.

2.1.1.1. Relationship with Anthropology

The road parameter effect originates from human activity in the area of landslides. They increase human activity with economic activity conducted in areas close to the roads [103]. According to the research, the frequency vibrations caused by cars on highways in turn cause landslides [104]. Many researchers have reported that roads along slope imbalance in study areas are the most influential anthropogenic factor [31, 40, 57, 63, 74, 75, 92, 105-110]

2.1.1.2. Relationship with Hydrogeology

Water can become concentrated in the imbalanced sections of the slope because of change on hydraulic roads during road construction [27]. Roads cause the emergence of ground waters on the surface because the roads interrupt the continuity of the slope, and the waters are collected by road drainage systems. Since inadequately or incorrectly projected drainage facilities are unable to securely evacuate these waters with precipitation after severe rainfall, they stand out as an element that triggers the landslides [94]. Indeed, Ataol and Yeşilyurt [98] observed in the sections in which there was slope imbalance in their study area that landslides with the water satiating the ground in rainy periods. Dahal et al. [111] encountered landslides that happened due to water that was unable to drain in the roads in their study area.

2.1.1.3. Relationship with Vegetation

Transportation lines that cause destruction in vegetation have a clear influence over landslides [22, 57, 112]. Some researchers reported that deforestation performed during road work caused landslides. For example, Petley et al. [113] correlated increasing landslide activity to road construction that caused changes in land use in their study in the rugged regions of Nepal. Dahal [97] said that highway access was established after deforestation in the study area but that the deforestation caused the deterioration of the side slope stability.

2.1.1.4. Relationship with Slope

Comprehensive excavations, the implementation of static and dynamic loads, water drainage, the removal of toe support, and vegetation are some of the most common acts that occur in road network slopes during construction. These load changes are also responsible for triggering landslides [3, 22, 24, 57, 87, 109, 113, 114].

2.1.1.5. Relationship with Load Change

During road construction in areas in which there are lithological units suitable for the landslides, slopes must be made to lean further to one side, slope loads must be decreased, and barriers must be made [98]. Generally, interrupting the lower slope during the construction of roads damages the natural condition of the slope. In this manner, the slope change causes landslides [2, 40, 69]. Zeng et al. [110] reported that landslides in the Enshi region occurred at slopes whose slope changed during road construction.

2.2. Effect of Distance to Faults on Landslide

Faults weaken rock masses and soil material. This makes them more susceptible to landslides [50]. Rocks and soils are made due to breaking and unbalancing by proximity to faults. Therefore it is considered as a potential factor contributing to landslide [88]. The effect of faults to landslides can be evaluated in two ways. Firstly, it increases the probability of a landslide with energy output. Secondly, due to increasing shear resistance to occur landslides [115]. Faults have a strong effect on the strength of the rock [93]. Faults generally reduce the strength of the surrounding rock mass by shear, seismic shake and other mechanisms [40, 74, 116]. Faults generate weakness zones in rocks [117]. Faults divide the rock mass into blocks or pieces, causing joints and breaks [47, 90]. In addition, they increase pore pressure and permeability by negatively affecting the zones of discontinuity, fracture and joints preexisting in rocks. This causes deep weathering zones [62, 118, 119]. In landslide susceptibility studies, the effect of faults is related to the constitutive of fracture and discontinuities of slope [120]. By reducing the shear strength due to intensive shearing [1, 56], it speeds up the weathering process [66] and increases the fracture ratio [121]. This causes rock slides [91]. It also produces discontinuities in rocks [120]. This results in sudden breaks [90] and fragmentation [45] in the rocks. According to Ruff and Czurda [122], the bedrock close to the structural elements is tectonically under tension. So they are highly unstable. Due to the faults, the soil becomes a resistless condition that can cause landslides [112].

2.2.1. The Effect of Distance to Faults with other Parameters on Landslide

Parameters make the area more sensitive to landslides. The lithology of the area is the first parameter that should be evaluated with the distance to fault parameter. It becomes a trigger by making weak zones in the rock weaker or creating new weak zones. Water condition is another parameter that should be evaluated together with the fault.

Of course, erosion and weathering must also be evaluated. Groundwater flow varies along these planes as weathering zones are formed. Groundwater zones can change because of the fault plane. As a result weathering zones comprise. Climate condition is one of the parameters that should be evaluated with this parameter. In addition, weather conditions make the environment prepared by the fault even more insensitive, especially in heavy rains. Also, slope and elevation are parameters that can be evaluated together with the distance to fault parameter. Relatively higher slopes and higher areas are more affected by faulting.

2.2.1.1. Relationship with Lithology

It has been observed that geological parameters, distance to the fault and lithology trigger landslides together under appropriate conditions [44].

Ercanoğlu [123] states that the main reason for approaching proximity to structural elements is that lithological units may become weaker due to the high tension and deformation characteristics of being close to these elements. Proximity to the fault, in general, not only affects the surface material structures, but also contributes to the permeability of the land causing slope instability [11, 31, 62, 92, 124-126].

Conforti et al. [62] stated that in metamorphic rocks in the study areas, as the distance to the fault lines decreases, the degree of rock breakage and weathering increases and therefore the area is prone to landslides. Kritikos and Davies [116] stated that the main fault, schist-origin mylonite and cataclasite, which passed through the study areas, are eroded and cause landslides. Aghdam et al. [24] determined that igneous rocks were broken and crushed by faults in the study area.

2.2.1.2. Relationship with Hydrology

The presence of a fault increases landslide susceptibility because faults can be related to abnormal groundwater conditions [127]. Selective erosion and the movement of water along the fault planes increase the possibility of landslides [57], [89-90]. Fault planes are suitable for improving infiltration and hydrostatic pressure on slope forming material [128]. Strong weather conditions in the faulting zone provide favorable conditions for landslides to occur due to the weakness it creates in the rock structure [58]. Petley et al. [113] stated that proximity to the fault directly triggered mass movements as well as mobilizing the material with subsequent precipitation after faulting.

2.2.1.3. Relationship with Slope and Elevation

Özşahin [46] states that in areas with a high slope in the study area, the proximity parameter to the fault triggers the landslides. Ahmed et al. [70] and Daneshvar [129] stated that the fault movements increase the sensitivity more with the height of the terrain.

2.3. Effects of Distance to Drainage Parameters on Landslide

Statistical analysis shows that there is a strong relationship between landslide distribution and distance to drainage [18]. However, the issue of which distances and how to use the main drainage or tributaries that form the drainage network on landslide formation is uncertain [81]. According to the literature, the general acceptance is that as the distance from the drainage line increases, the landslide frequency gradually decreases [1, 3, 4, 9, 10, 23, 130]. In other words, closer to the drainage, landslides are more likely to happen [7, 11, 58, 131-134]. Dai and Lee [135] and Mossa et al. [136] found a linear decrease between the distance to drainage and the landslide frequency.

The presence of water has an inverse relationship with the shear strength of a substance. Since the leakage of water near the drainage network is much more than these, the shear strength decreases near the drainage network.

Because as the percentage of water increases, the shear strength of the material tends to drop by half as much with an exponential behavior. According to this fact, high accumulation of drainage channels will lead to higher water penetration and consequently reduced shear strength of the formation [22, 128].

It is effective on landslides as they destroy the toe support over time due to the erosion caused by the weathering of the slopes. It increases the possibility of landslides to occur again [22, 125].

With the increase of the proximity value to the drainage network in any area, the effects of groundwater and surface waters will increase and therefore the surface will weather, making it more susceptible to landslides [137].

It moistens the stability of the slopes by moistening the part of the material that forms the slope below the drainage level or by saturating the part up to the drainage level with water [10, 76]. With the effect of water, plasticity and liquidity limits are reached and mass movements occur. Water increases the weight by reducing the angle of balance, reducing friction against it and facilitating movements [138].

Drainage networks form valleys in areas of steep slopes and create sensitive areas for mass movements. As water passes through an area, it washes the rough material on the surface. Besides the lateral pressure, water wants to penetrate fine-grained material. This influence can cause the entire substance to collapse as a result of the following process [22]. Hydrographic axes constantly change the slopes of the drainage and therefore can be considered as one of the main parameters in landslide manifestation [139].

There is maximum leakage along the slopes adjacent to the currents where materials have maximum permeability [140, 141]. It changes the surface geomorphology and controls the flow of water in landslide prone areas.

Due to the weathering effect of the drainage, it drags the materials from the toe point and eventually causes stepped landslides that trigger movements from the toe to the top elevation with lateral spreading [131]. Pore water pressure is affected, which affects susceptibility [30]. Timilsina et al. [44], in his works, considers the closeness to certain drainages as it applies. Because smaller drainages are less effective in large-scale landslides.

2.3.1. The Effect of Distance to Drainage with other Parameters on Landslide

Considering that landslides are frequently seen in river valleys, it is revealed that distance to drainage in the basin is an important factor along with slope and lithology in landslides [47]. Flow and area lithology affect erosion and weathering processes of drainage [142]. Groundwater exchanges surface water directly by protecting the drainage base, groundwater also provides moisture for riverside vegetation, affects surface water and controls the shear strength of slope materials, thereby affecting slope stability and erosion processes [143]. Groundwater in smaller, low-grade streams also provides most of the increased discharge during and immediately after storms [53].

2.3.1.1. Relationship with Erosion

There are landslides caused by erosion associated with drainage channels [57, 58, 62, 71, 77, 129, 133, 142]. In addition, the relationship between drainage and average erosion rate is a landslide-triggering relationship [144].

2.3.1.2. Relationship with Groundwater

The relationship between streams and groundwater is also important [22, 44, 53, 58, 77, 92]. Distance to drainage can affect the stability of the area as it affects underground flow [126]. With the increase of the proximity to the drainage network in any area, the effects of groundwater and surface waters will increase and therefore the surface will become more susceptible to landslides [137]. It also shows that groundwater tends to occur as a result of the flow of groundwater into drainages and drainages along the edges of the valleys and, as a result, affects shearing operations [78, 145, 146]. Groundwater basically provides base flow for all drainages and has a major impact on the amount of water and the chemical composition of the drainages [53].

2.3.1.3. Relationship with Vegetation

Drainage networks often affect vegetation by providing moisture for coastal vegetation [53]. The water supplied by the networks affect plant growth. The vegetation capillarity affect the mass movements, as the water in the ground takes up and evaporates with its roots, so that the leaked water holds a soil [138]. Proximity to drainages controls its impact on landscape evolution [116].

2.3.1.4. Relationship with Lithology

A drainage system developing on a surface is controlled by the surface's slope and the underlying rocks' types and attitudes [147]. Likewise, drainage channels significantly affect bedrock incisions [70]. Kritikos and Davies [116] argue that the riverbed reacts to the cut of the bedrock and that they have observed increased landslide erosion rates as the hill slope angles approach and exceed the threshold angle. Matebie et al. [148] determined that drainage plays an important role in changing the landscape by carving different rocks and cutting volcanic rocks and limestones at a depth of 1.5 km in the study areas. Pareek et al. [142] found that the density of landslides in the study areas is higher in the river basin than in quartzites and filites, which are more susceptible to weathering and erosion.

2.3.1.5. Relationship with Seismic

Xu et al. [6] argued that the landslides that were triggered by the Wenchuan earthquake mostly occurred along the drainage lines and as these areas were more susceptible to landslides due to drainage erosion.

2.3.1.6. Relationship with Slope

The proximity of the slope to the drainage structures is an important factor for stability. Considering that landslides are frequently seen in river valleys, it can be deduced that distance to drainages in the basin is an important factor along with lithology in landslides. Currents can adversely affect stability by eroding slopes or saturating the bottom of the material until it causes the water level to rise [52, 135, 149]. Pham et al. [150] determined that landslides occur in areas with 0-40 m distance from the drainage and slope angles greater than 15 degrees.

2.3.1.6. Relationship with Climate

The drainage flow is low when there isn't rain or an inflow of melted snow. Streams immediately provide more discharge during and after rain, snow or storms. The effect of rivers on landslides increases in all of these events [53, 57, 77].

2. Materials and Methods

The classification of linear parameters is created using buffers. There are important points to be considered in classification. First of all, the action distance must be selected. It is another important issue to determine the intervals. Metric system is used in measurements of distance. Mostly, meters are preferred rather than kilometers. Distances range from 50 meters to 1 kilometer. Class numbers can also vary between 3 and 15.

The effects of the linear parameters on landslides are evaluated in two manners according to the literature. The first classification notes the density of linear parameters, and the second classification calculates the distance between the linear parameter and the landslide. The literature mostly prefers the second method, landslide distance/proximity. Kumtepe et al. [8], in their study, they made buffer zoning for 2 km for roads and 1 km for drainages.

3.1. The Classification of the Road Parameter

Conducted classifications are over creating buffer zones. It is essential that different buffer zones are created along the lines through which roads pass to determine the effect of the road on the stability of the slope. The road proximity map determines the landslide areas and percentage distributions according to the degrees of road proximity through a comparison with the landslide inventory map. In the literature, studies that use equal distance for the general area are encountered. It was seen that some researchers performed classifications based on previously conducted classifications. For example, Özşahin [46] assigned the factor of distance to the road, considering the distinction that Yalçın et al. [143] made. Kouli et al. [87] noted landslide-triggering activity and data layers in road network buffer zones in the design of landslide susceptibility maps.

Differently, some researchers applied changes to their buffer distances according to the places they passed by. For example, Ayalew and Yamagishi [105] reported on various buffer thresholds in their study. The researchers' field observations found that the frequency of landslides was highest within 40 m of roads in mountains, within 100 m of coastal highways, and within 150 m in areas in which there are tunnels. For this reason, buffers were made at a length of 50 m along the edges of mountain roads, 100 m on coastal highways, and 150 m around tunnels. This showed that it is not possible to generalize a buffer application. Pourghasemi and Rossi [9] determined that the distance at which the effect of the road would be significantly reduced was 170 m. Despite this, some studies accept the effective distance from 40 m to 200 m [13, 105, 151].

It is necessary to randomly create different buffer thresholds within the study area. This also demonstrates the importance of field surveys for landslide susceptibility studies. Indeed, Champati Ray et al. [152] created buffer zones by conducting field studies to support the data they received from satellite images.

Researchers working in the local scale classify distances to highways in tens and hundreds of meters while mapping the typical landslide susceptibility [13, 69, 105, 111, 153, 154]. Considering the effect of roads on landslides, they create buffers around the roads [151, 155]. Kamp et al. [12] reported that 50% of landslides that occurred in their study area occurred because of building and road construction excavations.

An evaluation of the literature data sought to determine the range values and classifications used according to the selected studies. The review first sought to identify how many classification ranges researchers had identified. The percentage distribution graphs were created from the studies selected (Figure 1).

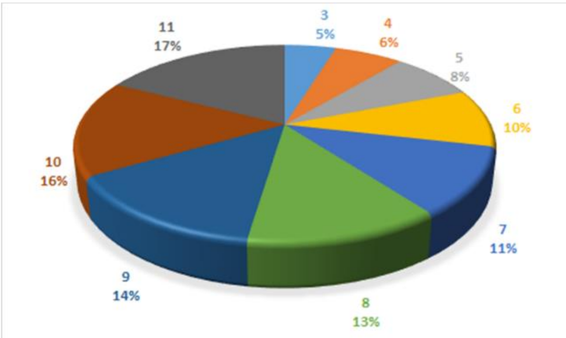

Figure 1. The percentage distributions for the buffer ranges created for the distance to the road according to the literature

When studying Figure 1, it was generally determined that researchers used 5 and 6 classification ranges. It is thought that the reason for this is that few classification ranges cannot adequately represent the area and that many classification ranges lead to confusion in calculations.

The range values used in the studies were sought to be identified. Some studies selected randomly were used for this. The range number percentage distributions were attempted to be identified (Figure 2).

It is seen from Figure 2 that the general preference in studies is 100 m ranges and that 50 m and 200 m ranges follow that. It is thought that larger ranges remove susceptibility and that smaller ranges are not meaningful or that there are much fewer landslides that fall in the ranges.

Finally, it was studied at what kind of approximate distance landslides occur and provide the results of the selected studies. The largest distances according to the literature are greater than 1000 m. The smallest distance is between 0 and 50 m. The effect of the road on landslides varies according to its role in the study area. Some researchers encountered landslides in areas up to 300 m, while other researchers found the most landslides occurred between 40 and 80 m.

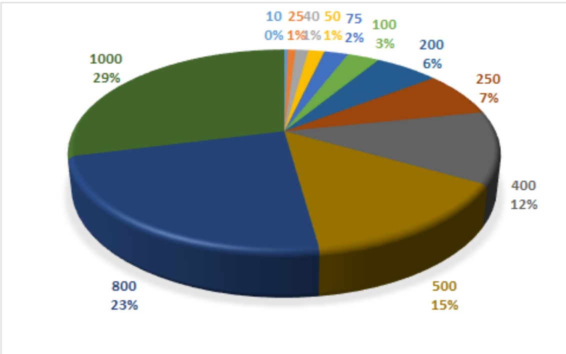

Figure 2. The percentage distribution values for the buffer ranges created for the distance to the road according to the literature

3.2. The Classification of the Fault Parameter

When using the proximity parameter for the structural features, more than one buffer zone is created by considering the different proximities. Taking this issue into consideration, many researchers have created different buffer zones. Researchers used meter and kilometer measurements in their studies. 50, 60, 100, 200, 250, 300, 500, 1000 m and 1 km are class ranges that are frequently used in the literature. Usually there are those who use equal class ranges as well as those who use unequal ranges. There are those who use different methods when determining the classification. It is available to those using previously specified class ranges.

Özşahin [67] used the classification prepared by Vahidnia et al. [156]. Dağ et al. [81] proposed a classification based on distances greater than m for sensitivity if it was determined as a result of land observations that the majority of landslides occurred in areas very close to the faults. Again, Gökçeoğlu and Aksoy [65] suggested a classification based on 0, 50, 100, 150, 200 and on distances greater than 200 m for sensitivity, as a result of area research, that the majority of landslides occurred in areas very close to faults. Rozos et al. [139], the classes of the buffer zones "1" nearest [0-50 m], "2" very close [51-100 m], "3" close [101-150 m], "4" middle far [151- 200 m] and "5" named far [> 200 m]. Likewise, Kayastha et al. [71] created 3 classes as [<100 m] very close, [100-500 m] close, [> 500 m] far. Özşahin and Kaymaz [112] classified the area as very highly sensitive [<100], moderately sensitive [100-1000], very lowly sensitive [> 1000] according to distance.

Alexakis et al. [2014] suggested a buffer distance of 500 m and Mathew et al. [2007] suggested a buffer distance of 300 m for main faults. Alexakis et al. [102] suggested a buffer distance of 250 m and Mathew et al. [66] suggested a buffer distance of 100 m for minor faults. Ramakrishnan et al. [118] created buffers for 3 types of faults in the area consisting of major and minor faults at 100, 50 and 5 m distances.

Some other buffer ranges used according to the literature are as follows;

There are those who restrict the buffers of the faults at a certain distance as well as those who don't set an upper limit. Mathew et al. [66] limited> 2 km for main faults and <2 km for minor faults. Ramakrishnan et al. [118] limited> 1 km for main faults and <1 km for minor faults. Saha et al. [157] prepared a 0.5 km wide buffer zone to represent the area of influence of structural tectonic properties on the landslides. Kumtepe et al. [8] used 2 km buffer zoning to create distance maps for the fault and these zones constituted the basis for classification. Özdemir [19] and Sujatha et al. [140] created scans in the study areas with a distance of 500 meters. Pareek et al. [142], 158] limited the buffer to 5 km. Apart from these, there are those who use disorderly and irregular class ranges [41, 44, 45, 57, 159, 160].

In the studies examined, it was observed that the researchers used a minimum of 3 and a maximum of 15 classes. The classification varies according to the study area. Some class numbers used according to the literature are as follows; It can be seen from here that 5 and 6 classes are the most preferred. This is followed by classes 3 and 4. In the studies examined, no researchers preferred 9, 12, 13 and 14 classes (Figure 3).

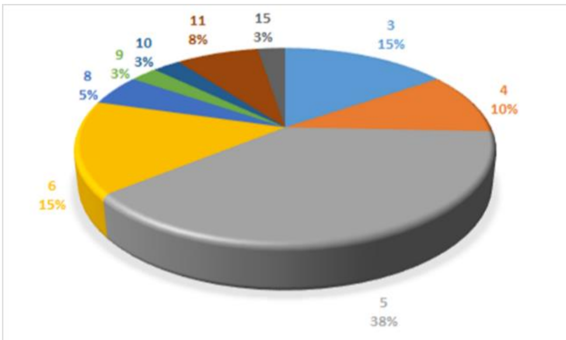

Figure 3. The percentage distributions for the buffer ranges created for the distance to the fault according to the literature

Uromeihy and Mahdavifar [161], Çevik and Topal [52], Özşahin and Kaymaz [112] stated that they expect landslides in areas below that 50 m by giving a lower limit while others no expect a landslide. Some class values that aren't observed in any landslides in the studies are as follows, Özşahin [46] encountered the lowest landslide frequency values in areas close to the fault line. The range values used in the studies were wished to be identified. Some studies selected randomly were used for this. The range number percentage distributions were attempted to be identified (Figure 4).

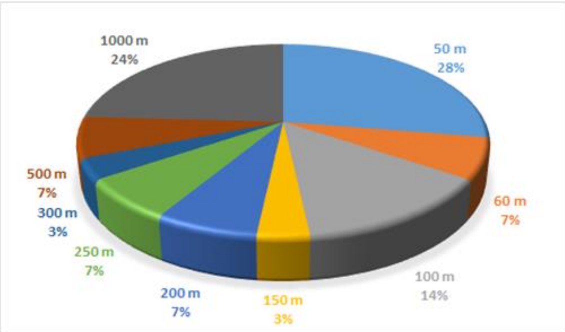

Figure 4. The percentage distribution values for the buffer ranges created for the distance to the fault according to the literature

It is seen from Figure 4 that the general preference in studies is 50 m ranges and that 1000 m and 100 m ranges follow that.

3.3. The Classification of the Drainage Parameter

The issue of which distances to pick and how to use the main streams or tributaries that form the drainage network on the landslide is uncertain [81]. In research, it is observed that landslides are concentrated after 150 m in general. In Akgün and Türk, [162], it is seen that more than 50% of the landslides are within 0-200 m. He et al. [163] determined that 85.99% of the landslides occurred in the study areas at 749.53 m distance from the drainage. They emphasized the high incidence of landslides in areas close to the river. Dai and Lee [135] found in their study that landslides gradually decrease as they move away from the stream.

Blesius and Weirich [13] and Dai ve Lee [135], on the other hand, determined the maximum distance as 300 m by calculating the effect of distance to the landslide with an equation. Özdemir [19] prepared a buffer showing the width of 250 m from all drainage lines. Sujatha et al. [140], Wang et al. [63], Gandhi [147] determined in their research that landslides occur within 500 meters of drainages. Aghdam et al. [24] stated that distances of more than 1000 meters have the lowest potential of landslides.

Some researchers have created a classification system and assigned values to the classification as follows; Özşahin and Kaymaz [112]; <100 m [very susceptibility], 100-250 m [highly susceptibility], 250-500 m [medium susceptibility], 500-1000 m [low susceptibility] and farther than 1000 m > [very low susceptibility]. Rozos et al. [7], [139]; nearest [0–50 m], nearest [51–100 m], near [101-150 m], middle far [151-200m] and far [200 m].

The most landslide distances in the studied areas; 0-20 m [164], 0 - 50 m [31], [71], [80], [160], [165], 0-75 [22],[62] 0-100 m [11], [38], [47], [57], [112], 0-150 m [53], [67], [166], 50-150 m [19], 0-200 m [1], [7], [147], [162], [167] 100-200 m [24], 100-250 m [59], 0-250 m [131], 0-300 m [52], 200-300 m [134], 500-1000 m [67],< 1km [124].

An evaluation of the literature data search determines the range values and classifications used according to the selected studies. The review was the first research to identify how many classification ranges researchers had identified. The percentage distribution graphs were created from the studies selected (Figure 5).

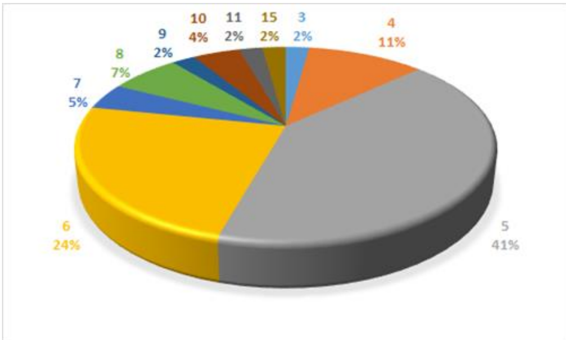

Figure 5. The percentage distributions for the buffer ranges created for the distance to the drainage according to the literature

The range values used in the studies were sought to be identified. Some studies selected randomly were used for this. The range number percentage distributions were attempted to be identified (Figure 6).

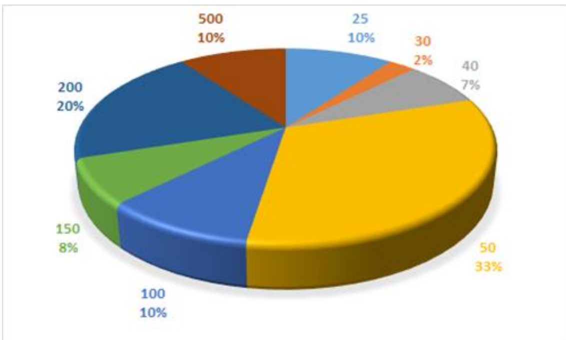

Figure 6. The percentage distribution values for the buffer ranges created for the distance to the drainage according to the literature

It is seen from Figure 6 that the general preference in studies is 50 m ranges and that 200 m and 25 m, 100 m, and 500 m ranges follow that.

4. Linear Parameters Case Study of Turkey

In this study, how the linear parameters were used in the literature, which class intervals were selected, in which class intervals landslide occurred, were determined. In that part of the chosen landslides in Turkey this study has tried to investigate the effect of these parameters. Primarily, for the study, 1: 25.000 scale landslide 64 sheets with 1: 25.000 scale were acquired from the General Directorate of Mineral Research and Exploration [MTA]. Later, road, fault and drainage maps of the areas were taken from the address of the institution "http://yerbilimler.mta.gov.tr/anasayfa.aspx". All maps are digitized. Table 1 was prepared as a result of analysis of distance to road, fault and drainage parameters.

Table 1. Areal distribution of landslides according to class ranges (m^2)

Distance	Fault	Road	Drainage	Total
0-50	15	45	11	71
50-100	15	60	11	87
100-150	17	57	12	86
150-250	33	87	26	146
250-500	74	165	70	309
500-750	64	135	68	267
750-1000	63	100	67	230
1000-1500	108	136	127	370
1500-2000	98	91.83	109	299
2000>	677	289	643	1608
Total	1163	1166	1144	3473

While calculating the class values, the three parameters were accepted simultaneously. Thirty-eight maps provided this requirement. Total landslide areas according to class ranges are given in Figure 7.

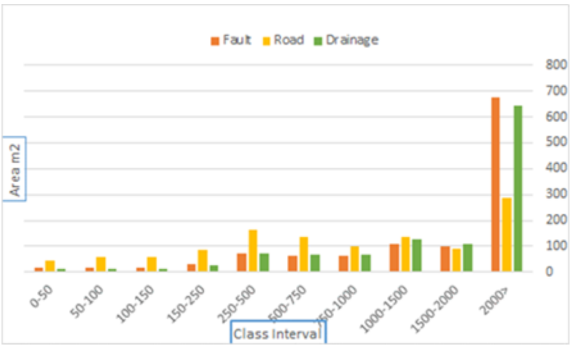

Figure 7. Class range distribution of 3 parameters according to total landslide areas

It is determined that landslides occur in areas close to the road, mostly in areas up to <1500 meters. The % percentage distribution of landslide areas by parameters is given in Figure 8.

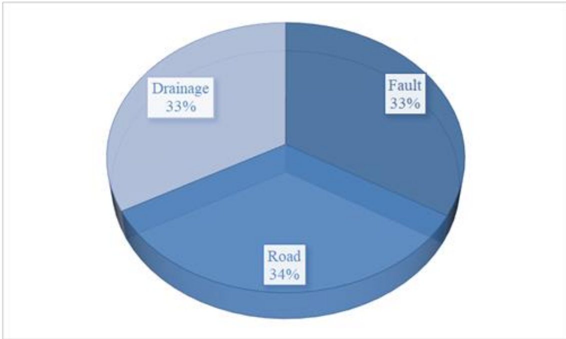

Figure 8. Distribution of landslide areas in% by parameters

Finally, the distribution of all parameters according to each class is given separately in Figure 9. Each graph was created with 50 m intervals, and the value ranges are provided in the chart titles.

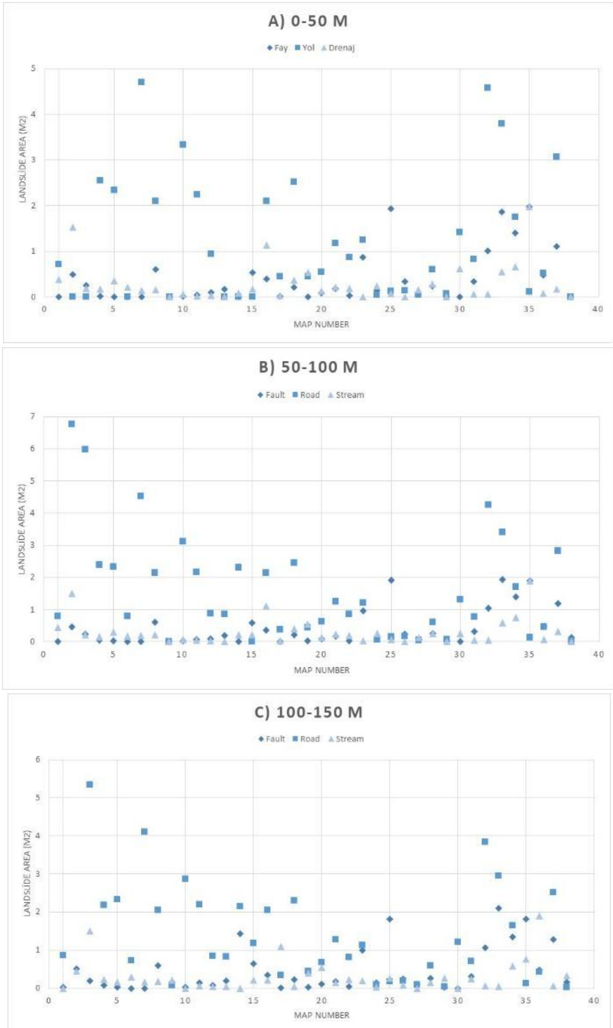

Figure 9. Landslide distribution graphs according to the class ranges of the parameters, According to the intermediate value, the variation of the distance to the road, fault and drainage in the areas according to the landslides, a) 0-50 m; b) 50-100 m, c) 100-150 m, d) 150-250 m, e) 250-500 m, f) 500-750 m, g) 750-1000 m, h) 1000-1500 m, i) 1500-2000 m, j) >2000 m

Figure 9. (Continued) Landslide distribution graphs according to the class ranges of the parameters, According to the intermediate value, the variation of the distance to the road, fault and drainage in the areas according to the landslides, a) 0-50 m; b) 50-100 m, c) 100-150 m, d) 150-250 m, e) 250-500 m, f) 500-750 m, g) 750-1000 m, h) 1000-1500 m, i) 1500-2000 m, j) >2000 m

5. Results

According to the literature, classes ranging from 3 to 15 were selected. In this study, 10 class ranges were preferred for each area. It was observed that different equal class ranges from 50 m to 1000 m [1 km] were used. Apart from that, scattered class ranges were also preferred. In this study, a scattered class range was preferred [0-50, 50-100, 100-150, 150-250, 250-500, 500-750, 750-1000, 1000-1500, 1500-2000 and> 2000 m].

As can be seen from here, the range of classes' susceptibility to one area may be unfavourable for another area. While landslide frequency values close to the fault are high for one area, it can give the lowest landslide frequency values for another area.

It was seen that positive results were obtained for certain areas. It was seen that it was useful to use the classification range values previously used, based on the character of the study area. For example, 50 m, 100 m, 250 m, 500 m range classification, classification range value used in previous studies, was evaluated. It was seen that it was useful in half of the selected map section. This demonstrates that classification ranges must be selected through test bias in future studies. It is emphasized that field surveys are a useful method for research that cannot be conducted. When all map sections were evaluated, it was seen that more than 80% of landslides occurred in a distance of less than 2 km. It is seen that 55% of landslides occurred in a 1 km area. As a result, a limited number of studies were tested with a certain number of map sections. However, by creating options for the classification ranges and classifications that can be selected, a study was sought to provide ideas for future studies.

Out of 64 layouts, 5 of them don't have 3 parameters. There was no fault in 59, 9 in 7, road in 7 and no drainage in 9. In the study, the class ranges with the most landslides are listed as follows: <2000, 1000-1500, 250-500, 1500-2000, 500-750, 750-1000, 150-250, 50-100, 100-150, 0 -50 meters. Landslides are the most in order; the road can be seen in areas close to drainage and fault.

6. Conclusions

Landslide susceptibility studies, which have been going on for years, still continue today with the application of different methods and parameters. In the studies, performed methods are held in high importance, meanwhile parameter selection is ignored. Each field has a unique structure, and the parameters of that field should be selected accordingly. Parameter usage is not standard. should be selected according to the area. The same rule applies to subparameter class selection. This study is very different from a standard susceptibility study. Weight values are not given to the parameters; only the class ranges of the parameters are evaluated. Instead of comparing with other parameters, linear parameters are evaluated within themselves. This study shows that the selected class range is as important as the selected parameter. And this constitutes a more important issue than the method used. The distances given here also shed light on what kind of changes may occur in the studies. The point that should be evaluated before coming to the weights of the parameters is the distances of their values with class intervals. The ratio of the application of large values to small values should be considered. The distances given in this study will shed light on the future researchers who will use these parameters, and the researcher will consider the application distances of these parameters in the field.

Parameter selection is particularly important in the preparation of landslides susceptibility maps. A literature review constitutes the first step of these types of studies. While there are general classifications for almost no parameters, techniques performed previously in similar studies are implemented. This study sought to determine and implement the distance to road, fault, drainage classifications and range values used in the literature.

Therefore regarding the answer to the question "how effective is the distance to linear parameters in a landslide" these are the parameters that vary according to the study area and are very effective according to their location.

Declaration of Ethical Standards

The author of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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